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N.G. BORISENKO, A.A. KOLOGRIVOV,
YU.A. MERKUL`EV, M.V. OSIPOV , V.N. PUZYREV,
A.T. SAHAKYAN, A.N. STARODUB, B.L. VASIN

ABOUT HYDRODYNAMIC EFFICIENCY OF INTERACTION OF LASER RADIATION WITH MATTER

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About hydrodynamic efficiency of interaction of laser radiation with matter*

N.G. BORISENKO, A.A. KOLOGRIVOV, YU.A. MERKUL'EV, M.V. OSIPOV, V.N. PUZYREV, A.T. SAHAKYAN, A.N. STARODUB, B.L. VASIN

P.N. Lebedev Physical Institute of RAS, Leninsky prospect 53, 119991 Moscow, Russia

ABSTRACT In our paper are presented the results of the direct experiments carried out for the first time to measure the hydrodynamic efficiency of interaction of the laser radiation with matter. In these experiments we have used the ballistic pendulum method. Under the laser radiation energy of 9,4 J the hydrodynamic efficiency of interaction of this radiation with Al target is equal to 4.3 %.

1 Introduction

The complex investigations of the hydrodynamic phenomena taking place under interaction of the laser radiation with matter are great importance because the basic parameter of the ablation stage is the hydrodynamic efficiency or relation of the energy of the non-evaporated part of target to full energy of the laser radiation. This efficiency defines the energy balance in the thermonuclear system up to the burning stage and the maximum value of the fusion fuel which may be compressed under given laser energy up to high density [1, 2].

Direct experiments have been made on measuring the efficiency, since an ambiguity of theoretical description makes it difficult to interpret indirect experiments.

2 Experiment and results

Laser radiation of a solid-state neodymium laser "KANAL-2" [3] with pulse duration of 2.5 ns has been directed to the experimental vacuum chamber (Fig. 1). The

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laser energy, both heating and reflected, has been registered with the help of the calorimeters.

A known method of ballistic pendulum [4] was used to measure the momentum of target due to the laser irradiation. A pendulum was suspended to the adjusting device in the upper part of the chamber. The pendulum presented a thin low-mass (as compared to the pendulum mass) rod and a target holder fixed at the end of the rod. The plate-shaped targets made of different materials have been placed at the ends of the holder. The pendulum deflection indicator has been placed in the holder bottom part. The pendulum length was 145 mm, and the mass, 6.195 g (without targets).

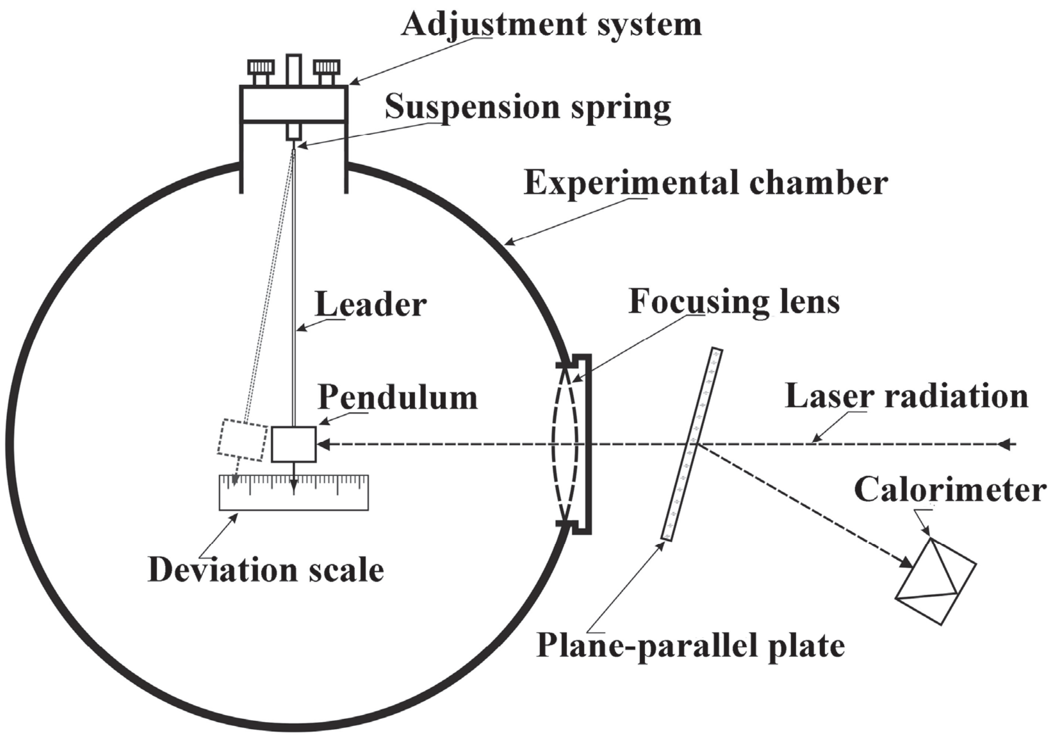


FIGURE 1. Scheme of experiment

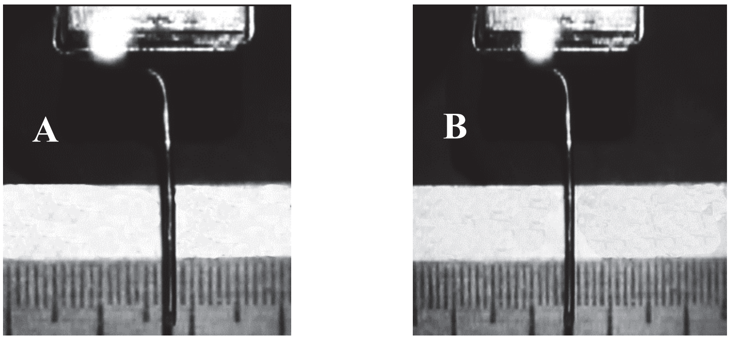


FIGURE 2. Frames of high speed velocity photography of pendulum deflection. A: $n = 0$; B: $n = 43$ (n – number of frame)

The pendulum deflection under the action of a laser radiation onto the target has been registered by a video-camera with the frame rate 240 s^{-1}, and the deflection value (Fig. 2) has been measured with a ruler placed in the experimental chamber just behind the pendulum deflection indicator (from the side of a video camera). The time of reaching the maximum deflection was calculated by the number of frames from the moment of the laser pulse incidence onto the target and the known frame rate.

To determine the kinetic energy of laser plasma ions one employed the mass-spectrometric and ion-collector measurements.

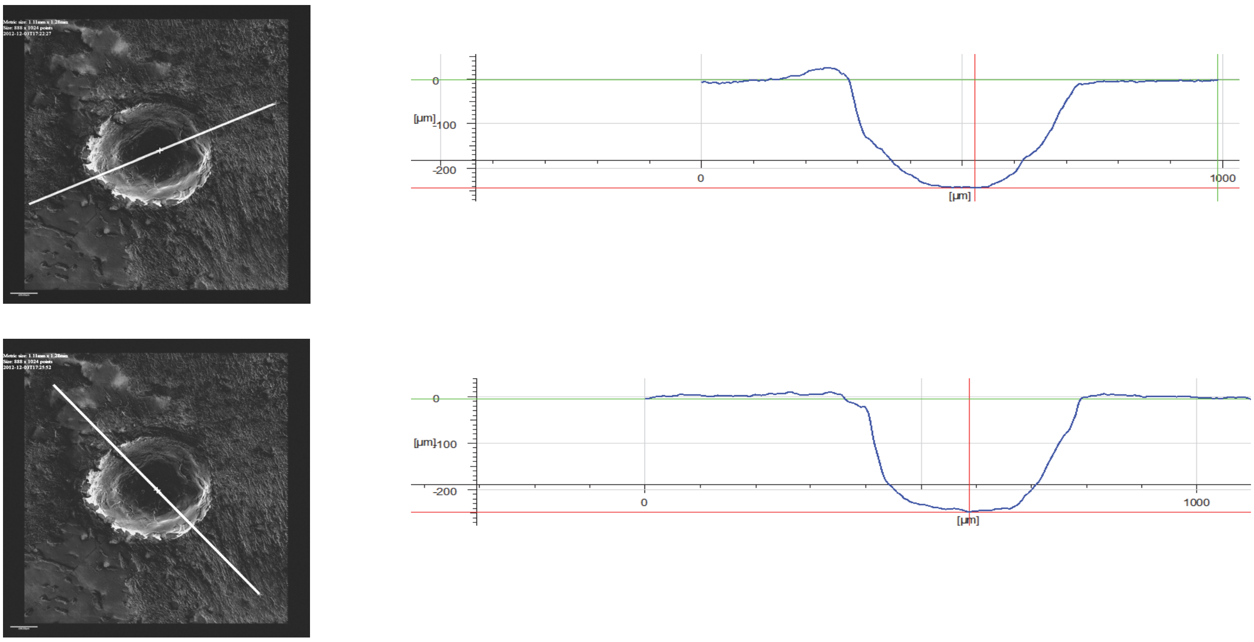
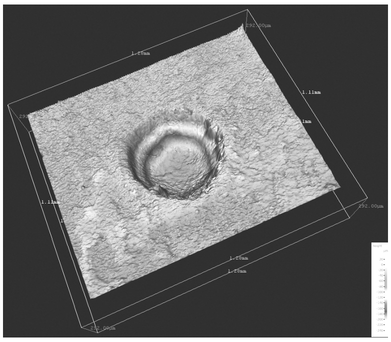


FIGURE 3. Photo of crater and the crater profiles in indicated directions (red lines). Laser energy is equal to 9.4 J



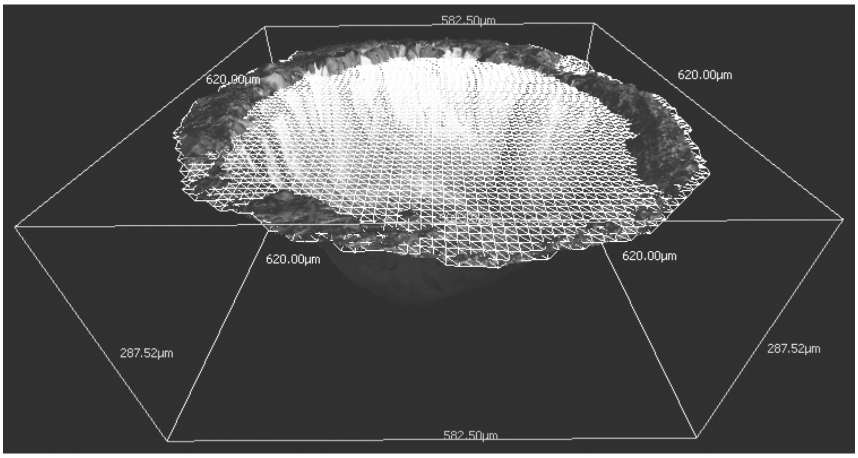


FIGURE 4. 3D image of crater. Laser energy is equal to 9.4 J

A crater has been formed on the target surface as a result of laser interaction with the target matter, and the evaporated matter mass has been calculated by the crater volume (Figs. 3, 4). The morphological investigations have been made with raster microscope "Helios" [5].

For Al target and the laser energy incident onto the pendulum being 9.4 J, the pendulum momentum was 1.89 kg m^2/s^2; the pendulum angular velocity, $1.03 \cdot 10^{-1}$ rad/s; the pendulum linear velocity, $1.5 \cdot 10^{-2}$ m/s; the pendulum impulse, $10.8 \cdot 10^{-5}$ kg m/s; crater volume, $2.14 \cdot 10^{-11}$ m^3; evaporated matter mass, $5.76 \cdot 10^{-8}$ kg; evaporated matter velocity, $3.74 \cdot 10^3$ m/s. Accordingly, the hydrodynamic efficiency of laser-target interaction made 4.3 %.

3 Conclusions

We have presented the results of the direct experiments carried out for the first time to measure the hydrodynamic efficiency of interaction of the laser radiation with matter. In these experiments we have used the ballistic pendulum method. Under the laser radiation energy of 9.4 J the hydrodynamic efficiency of interaction of this radiation with Al target is equal to 4.3 %.

The measured value of hydrodynamic efficiency is ten times less than its possible maximal value, and several times less than its theoretical estimations obtained from indirect experiments. This means that the expected minimal value of laser energy needed for ignition of the pure fusion can be much greater because the value of such energy depends strongly on the hydrodynamic efficiency. From this one can conclude that the hybrid fusion-fission scheme of energy production [6, 7] is more preferable.

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